CHAPTER 2
COAL RESOURCES TO SUPPLY POWER STATIONS

The goal of achieving more energy independence for Armenia initiated an effort to evaluate domestic solid fuel reserves with a focus on the coal resources of Armenia. In the past, the coal resources of Armenia were essentially ignored because they were far less important that other Soviet coal resources. In addition, natural gas and mazut were plentiful and relatively inexpensive so marginal coal deposits held less value.

The coal resources of Armenia are found throughout the country in relatively small deposits that to date have been inadequately explored. The coal can be found in occasional outcrops, generally occur in thin seams, and in some cases are mined for fuel. Because the deposits were inadequately explored, USAID enlisted the United States Geological Survey to assist Armenia in defining these resources. The hope for this effort was identification and location classification of any promising coal reserves.

In the mining sector, coal or similar mineral of potential value that is found initially is simply defined as a resource. As more information is gathered to define the extent and utilization of the deposit it becomes classified by distinctions which indicate the economic mineability and quality of the mineral in the market place. The Russian and U.S. systems used for this purpose are similar in that they strive to develop the information necessary to define the mineral deposits in a fashion that addresses quality, volume, and economic issues. One primary difference between the two systems is the definition of economic reserves.

In the case of Armenia, few of the coal resources have been identified as economic reserves. Generally speaking, in non-technical terms, resources are considered as mineral resources that are uneconomic or are inadequately defined to establish if they could be economic or marketable. Reserves are defined as resources that have been defined as mineable and economic and provide the mine with an inventory of mineral that can be mined and sold in the future for economic profit.

Coal resources in the U.S. employ the U.S.G.S. classification system to define reserves into four prominent classifications roughly correlating to the Soviet system of reserve classifications, as shown in Table 2-1. In the U.S. coal industry, the U.S.G.S. classification system is used to define the economic reserves that a mine can confidently rely on for decisions regarding mine construction, development, and economic decisions. It is commonly accepted that in order to support investments in feasible mining projects that reserves must be classified as demonstrated. This includes the sub-classifications of measured and indicated noted in Table 2-1. Therefore, in order to consider reserves as potentially mineable and economic, they must be classified as A, B, or C1 reserve classifications in the Soviet system.

Table 2-1
Comparison of U.S.G.S. and Armenian Coal Resource Classification Systems

System	Classifications					
Soviet	A	B	C1	C2	P1	P2
U.S.G.S.	Measured		Indicated	Inferred	Hypothetical	

2.1 COAL RESOURCES OF ARMENIA

The USGS[1] analyzed the coal resources of Armenia and provided the summary in Table 2-2 as defined by Soviet resource classification standards. The information above shows that there is potential for up to 147 million tonnes of coal resources to qualify as coal that could possibly provide for economic coal reserves to support a coal-fired power station. However, as mentioned above, the categories that should be focused upon here are the A, B, and C1 classifications. The identified coal resources in these classifications are estimated at 6,001,000 tonnes plus any of the Shamut C2 coal resources that could possibly be classified as a C1 classification type. These data only indicate that coal exists as a resource that might be economic so they must be analyzed to determine how much, if any, of the coal can be economically mined.

Table 2-2
Soviet Classification of Coal Resources in Armenia
Thousands of Metric Tonnes

	Coal Tonnes by Resource Classification						
Coal Deposit	A	B	C1	C2	P1	P2	Total
Antaramut (4)	1,416		4,102	26,079			31,597
Shamut (1)			4,055		10,592		14,647
Ijevan (2)				9,780	88,000		97,780
Jajur (1)	483						483
Nor Arevik				23			23
Jermanis (3)					2,251		2,251
Total	1,899		44,039		100,843		146,781

Note:
(1): USGS Recalculation of Resources based upon Armenian geologic data.
(2): Armenian Officially Reported Resources.
(3): The classification of this resource was not defined within the USGS reports. We classified the reserves as P because seams are lenticular and thin, <0.5m, and poorly defined.
(4): Based on the economic mining study and C1 resource reported by the USGS, we have classified the total tonnage estimated by USGS in the categories shown.

[1] Coal Exploration and Resource Assessment of Armenia, U.S. Geological Survey Open-File Report 99-567; Brenda S. Pierce, p. 4-9

Of these coal resource deposits, that U.S.G.S. recommends (in the text referenced above) that Jajur, Nor Arevik, and Jermanis not be pursued any further as candidates to find additional coal reserves. These U.S.G.S. recommendations are provided below:

Jajur:

> "Localized drilling is needed to restart and expand the small mining operation (the sited of a USAID-funded strip mine), if continued mining is desired. The Jajur deposit may be an important local resource, especially for use in Gyumri. However, larger scale regional exploration is probably not warranted."

Nor Arevik:

> "Detailed field work and geologic mapping by USGS indicate that the Nor Arevik coal field is sufficiently understood. Because net thickness is not great and the aereal extent of the coal probably does not extend much beyond that already studied, the Nor Arevik coal deposit can probably be considered a local resource. No further exploration is recommended."

Jermanis:

> "Detailed field work and geologic mapping by USGS indicate that the Jermanis coal field is not very laterally extensive and occurs in a fairly structurally complex area. In addition, net coal thickness is not great. The Jermanis coal field can be considered a local resource. No further exploration is recommended."

These conclusions indicate that the three coal deposits are inadequate for power generation. There are insufficient volumes of coal available in these deposits to support a coal-fired power station. Hence, each of the remaining deposits (Antaramut, Shamut, and Ijevan) need to be examined separately in order to understand the potential each deposit has to offer.

2.2. ANTARAMUT COAL RESOURCE ASSESSMENT

The Antaramut coal deposit is located about 15 kilometers north-northeast of the town of Vanadzor in north central Armenia. The topography in the vicinity of this coal deposit is hilly as shown in Figure 2-1, below. Here, the U.S.G.S. took a coal deposit that was expected to contain insignificant coal resources and identified a coal deposit containing a significant coal resource. Prior work conducted by geological professionals concluded that there was little coal and the resource volume was not calculated. The USGS work product projects a coal resource of about 32 million tonnes, as shown above in Table 2-1. The exploration also successfully identified an area of the deposit wherein it is very likely that economically mineable coal resources exist. Although additional development drilling is necessary to confirm the coal reserve assumptions, it appears that 1.4 million tonnes of coal could be recoverable and economic if additional drilling confirms the reserve quantity and quality.

Figure 2-1
Antaramut Deposit Area Topography

According to the U.S.G.S.[2] the coal at Antaramut is of Upper Eocene age and is primarily contained within two coal beds, each about 1 meter thick. Analysis of drill hole information shows seam thickness generally ranging from 0.8 to 1.3 meters but occasionally as high as 1.8 meters. The coal is of high-volatile bituminous rank. The estimated quality of the coal, as determined from U.S.G.S. data, is shown below in Table 2-3.

Studies by the U.S.G.S. indicate that this coal can likely be beneficiated with the ash content being reduced from 40% down to a level of 20 to 25%.

A pre-feasibility study conducted by the U.S.G.S. was completed for the 1.4 million tonne portion of the coal reserve. This pre-feasibility study provides a cost estimate of developing this particular coal deposit in Armenia which can be used as a basis for cost estimation for coal deposits which could employ a contour haulback mining method complemented by an auger mining method. This study concludes that the recoverable economic coal reserve is estimated to be 916,000 tonnes.

[2] Coal Exploration and Resource Assessment of Armenia Program, Implemented by the U.S. Geological Survey, Funded by the U.S. Agency for International Development In Cooperation with the Republic of Armenia Ministry of Environment, Brenda S. Pierce, p. 47-54.

Table 2-3
Antaramut Coal Sample Quality Characteristics

Quality Parameter	Units	Upper Bed	Lower Bed
Calorific Value – Moist Mineral Matter Free Basis	Kcal/kg	7,800	8,600
Ash Content – As Received Basis	%	43	41
Moisture Content	%	5.2	4.9
Sulfur Content	%	3.2	2.8
Calorific Value – As Received Basis	Kcal/kg	4,250	4,630
Volatile Matter – Dry Ash Free Basis	%	24.7	26.5

The coal resources provided by U.S.G.S. in Table 2-2 indicate 4.1 and 26.0 million tonnes of C1 and C2 class coal, respectively, within the Antaramut coal resource. The coal dips away from the ground surface in the north at about 15° to the south while topography and layers of earth, or overburden, overlying the coal increase towards the south. This combination of decreasing coal elevation along the dip coupled with the increasing elevation of the ground surface overlying the coal creates a coal resource that has very limited potential for economic surface mining. Given the structural environment within which this coal exists, most of the Antaramut coal resource would have to be mined using underground mining techniques. These techniques are not expected to be economically feasible because the seams are too thin and inconsistent for efficient underground mining.

The portion of the coal reserve where it outcrops at the surface was included in the pre-feasibility study conducted by the U.S.G.S. The potential for economically mineable reserves for the Antaramut coal deposit are assumed to be about 900,000 tonnes. It should be mentioned that there is a small section of coal in the southeastern portion of this deposit which does outcrop, possibly providing some additional coal reserve potential but it is likely to contribute a small quantity, if any, to the reserve potential.

In summary, the potential for economically mineable reserves at the Antaramut deposit is assumed to be about 900,000 tonnes of coal. There is other coal resource in this deposit but it is unlikely that the coal is cost effective because it is too thin for economic underground mining and has limited surface mining potential. No further work at the Antaramut deposit is recommended.

2.3 SHAMUT COAL RESOURCE ASSESSMENT

The Shamut coal deposit is located about 30 kilometers northeast of the town of Vanadzor in north central Armenia. The deposit is located just north of the Martsiget River. The topography of the Shamut site is rolling hills as can be seen in Figure 2-2.

Figure 2-2
Shamut Deposit Area Topography

The coal bearing section, according to prior geologic reports, includes three primary beds that continuously extend over a length of 4 kilometers from the village of Shamut east to the village of Atan. The resource calculations of 14.6 million tonnes made by the U.S.G.S.[3] includes everything with coal as described by geologists during logging exercises, only ignoring slightly carbonaceous beds. In this calculation, there was no minimum bed thickness or maximum ash criteria established. This calculation thus represents a true resource calculation and must be analyzed in depth for mineability and economic realities. The Shamut deposit contains beds that should be properly described as carbonaceous shale beds rather than coal beds because the ash content in the beds is greater than 50%. The deposit is, therefore, more accurately described as the Shamut coal and carbonaceous shale deposit when considering the resource calculations referenced above in Table 2-2.

The referenced reserve report by the U.S.G.S. does not provide any summary details to allow inspection of the thickness of the coal/carbonaceous shale seams or the relative quality resulting from the calculation of the total resources. By employing Table 8 of the referenced report, some information on the three primary seams identified for the resource can be discerned. These seams are defined by the U.S.G.S. as the upper, middle, and lower beds. This data is representative of sixteen separate sampling points through the resource area. The information has been recast on a bed (or seam) basis in Table 2-4.

[3] The Shamut Coal Deposit, North-Central Armenia by Brenda S. Pierce, Gourgen Malkhasian, and Artur Martirosyan, Advance Copy of a U.S. Geological Survey Bulletin which is as of yet un-numbered. Table 15.

Table 2-4
Characteristics of the Coal and Carbonaceous Shale Beds
Shamut Deposit

Seam	Thickness Meters	Calorific Value (a)	Calorific Value (b)	Moisture % (c)	Ash % (c)	Sulfur % (c)	Volatile Matter % (c)
Upper Bed							
Average	1.45	5,303	2,132	4.39	57.95	1.25	48.97
Minimum	0.78	4,478	1,604	1.17	40.69	0.40	40.00
Maximum	3.93	6,800	3,896	8.89	63.45	3.12	53.72
Middle Bed							
Average	1.22	5,536	2,265	4.70	57.07	1.00	49.59
Minimum	0.81	3,255	886	0.94	43.30	0.35	41.77
Maximum	1.45	6,969	3,914	8.34	71.34	1.90	60.14
Lower Bed							
Average	1.63	4,881	1,783	3.62	62.10	1.34	53.39
Minimum	0.34	4,012	1,164	1.30	53.12	0.29	50.00
Maximum	4.20	6,377	2,870	7.73	68.56	3.00	58.77
All Beds (d)							
Average	1.42	5,270	2,083	4.29	58.71	1.19	50.27
Minimum	0.34	3,255	886	0.94	40.69	0.29	40.00
Maximum	4.20	6,969	3,914	8.98	71.34	3.12	60.14

Note:
a: Dry – Ash Free Basis (As reported by U.S.G.S. review of Armenian data).
b: As-Received Basis, our calculation.
c: Dry Basis
d: Average of all Data Points.

This information shows that the deposit should be classified as a carbonaceous shale deposit because the average ash content is about 59%. The deposit shows an indication of low moisture and sulfur content, at 4.3 % and 1.2%, respectively. The average as-received calorific value is estimated at about 2,100 kcal/kg, which is about equivalent to 3,800 btu/lb.

The coal section was analyzed to determine a likely mining section. This work shows the mining section is highly variable and includes several non-carbonaceous layers requiring removal to maintain the typical quality values shown above, even without considering dilution from mining operations. Table 2-5 shows two drill hole sections of the mining zone that display the range of layers requiring selective mining during the mining process. The minimum thickness one would desire to work with from a surface mining perspective is at least 30 centimeters. It can be seen in the table below that it is difficult to add carbonaceous and non-carbonaceous layers together to form a mineable zone without adding significant ash into a mineable section. It can also be seen that carbonaceous layers occur that can not be mined because they are too thin.

The same principle applies to some non-carbonaceous layers that can not be removed from between two carbonaceous layers because the resultant mining section would have more ash than the ash content of the two seams combined. In essence, it is difficult to mine all the multiple layers of carbonaceous and non-carbonaceous materials because of the thickness of the individual layers involved. It would also be more expensive to mine the deposit in this fashion if several selective mining operations were required to produce a run-of-mine product with ash content as low as possible from the reserve. We have assumed that a maximum of 70% in-situ ash is acceptable as mining sections in Table 2-5 were selected.

There are samples of coal within the resource indicating that true coal beds with ash below 50% do exist. Analyses of these individual samples show an average thickness of 0.4 meters and an average ash content of 41%. If this coal could be selectively mined, the ash content would increase by dilution caused by the mining process. In addition, many of the sampled sections could not be mined individually and should be mined in a thicker section with other coal containing layers.

In summary, in order to develop adequate quantities of fuel for a power station, a larger vertical mining section of coal must be mined. The ash within the section mined will increase to the point where this resource then would, on the whole, produce a very low quality carbonaceous shale, much like or worse than that shown in the summary in Table 2-4.

It can be seen from Table 2-5 that the only feasible underground mining section is the middle coal/middle coal shale section, measured at 1.7 and 1.2 meters thick in drill holes 8/53 and 9/53, respectively. This is the only underground mining section that could possibly produce a product with an ash that is reasonable. It can be seen that both the thickness and the ash content within this section varies greatly, from 1.2 to 1.7 meters and from 44 to 54% ash, respectively, just between these two sample points. It can be seen by comparing this mineable underground thickness to the total carbonaceous shale thickness of 2.8 to 3.4 meters, that a reduction in the mineable section would reduce the mineable resource thickness, and thus the available mineable resource, by 40 to 50%. The thickness of the middle carbonaceous layer is not consistent and generally is less than one meter thick, relative to a mineable section. A quick audit of the coal thickness of likely mining sections shows the coal seams change frequently in quality and thickness. It is doubtful that a reasonable mining section height could be established within the reserve in order to mine this material with underground methods while producing a reasonable ash product.

This deposit could be best mined by surface mining techniques calling for initiation of mining at the crop and progressing with individual pits either perpendicular or parallel to strike. This technique would develop a higher quality product with values possibly similar to those shown in Table 2-4. Prior studies on coal washability do not provide a reliable guide; thus, it is undetermined if beneficiation[4] may result in a significantly lower ash product.

Table 2-5
Shamut Typical Mining Sections

Drill Hole 8/53				Drill Hole 9/53			
Layer Description	Thickness Meters	Mining Zone	Ash % (1)	Layer Description	Thickness Meters	Mining Zone	Ash % (1)
Upper Coal Shale	0.50	1	52%	Upper Coal Shale	0.38	1	58%
Sandstone	0.74			Argillaceous Sandstone	0.89		
Middle Coal Shale	0.19		51%	Middle Coal	0.41	2	52%
Clayshale	0.09			Argillaceous Sandstone	6.06		
Middle Coal Shale	0.23		55%	Lower Coal	0.09		29%
Sandstone	0.55			Argillaceous Sandstone	1.08		
Middle Coal Shale	1.70	2	54%	Middle Coal	1.20	3	44%
Sandstone	0.09			Argillaceous Sandstone	0.55		
Lower Coal Shale	0.09		65%	Lower Coal Shale	0.50	4	54%
Sandstone	0.37			Argillaceous Sandstone	2.41		
Lower Coal Shale	0.19		51%	Lower Coal Clayshale	0.24		57%
Lower Coal Clayshale	0.46		75%				
Total Carbonaceous Shale	3.36				2.82		
Total Mining Section Thickness	2.30				2.49		
Total non-Carbonaceous Shale	1.84				10.99		

Note:
1: As Received Basis

The resource estimate for Shamut projects a maximum of 14.7 million tonnes for the current strike length assumption of four kilometers. This estimate includes sections of non-mineable layers. With an average calorific value of 2,100 kcal/kg, a 50 MW power station would require approximately 600,000 tonnes of carbonaceous shale per year. Over a 35-year life, the total mineable reserve required would be 21 million tonnes.

U.S.G.S., though, is of the opinion that this resource has a greater strike length than that assumed by prior Armenian studies and believes that a strike length of eight kilometers could be possible. If this is the case, then it is possible that the total reserve could double to 28 million tonnes of resource. It is not possible at this point to determine if the necessary 21 million tonnes of

[4] Beneficiation is the process of upgrading coal by the removal of ash, sulfur or moisture.

carbonaceous shale is recoverable from the Shamut coal resource area. But it is unlikely adequate reserves could be developed because underground mining would be required and that method does not appear to be feasible. Further investigation of available information and additional geological data is required.

Our analysis above has shown that much of the reserve could very well be lost because carbonaceous layers are too thin for mining and because combining layers into mineable sections would develop a product with very high ash. In addition, a more selective mining process would adversely affect the mining economics and reduce the available resource volume. A review of the information available on the reserve suggests that a significant portion of this deposit may not be recoverable and that it would be a very low quality product because of excessive ash.

The Shamut carbonaceous shale deposit may not provide a fuel resource large enough for a 50 MW fluidized bed power station. In addition, the calorific value of the beds of carbonaceous coal, at 2,100 kcal/kg, is extremely low. The large quantity of ash generated by burning this fuel would require that the power station be located near the Shamut site in order to reduce transportation and ash handling costs to economical levels.

It would be necessary to consider environmental concerns regarding relocation of the power station in order to consider this option further. The remoteness of the Shamut site will require additional capital investment, such as a new 20-kilometer access road, to enable mining and haulage operations. Because of the remote location of this resource, the low heat content, mineability issues, and the lack of local infrastructure other resources should be considered before the Shamut site.

The Shamut site should only be considered as a carbonaceous shale deposit that would produce a product with ash in excess of 50%. No further work on this deposit is recommended until it is determined that other resource investigations have eliminated all prospects with better economic potential.

2.4 IJEVAN COAL RESOURCE ASSESSMENT

The Ijevan coal resource area is located northeast of the town of Ijevan in east-northeastern Armenia. The topography near the Ijevan coal deposit area includes steep hillsides as can be seen in Figure 2-3, below. The coal deposit has not yet been fully evaluated by the U.S.G.S. but they are of the opinion the coal field is larger than that expected by the Armenian geological professionals. In the past, the U.S.G.S. has proposed drilling in the Ijevan area but because the field is within a virgin forest area, there has been opposition from the Ministry of Environment. U.S.G.S. is of the opinion that these environmental objections can be dealt with in an appropriate fashion to allow further exploration of the Ijevan coal deposit.

Resources reported officially by the Armenian government are 9.8 million tonnes of C2 and 88 million tonnes of P classification. The U.S.G.S. determined that this deposit is geologically complex. In the current area of mapping, dips are very steep.

Figure 2-3
Ijevan Deposit Area Topography

According to the U.S.G.S.[5] the coal is of Jurassic age and has a coal bearing section thickness from 25 to 26 meters. Only one coal bed has been identified and it is about 16 to 18 meters thick. The beds dip down at a very steep angle, from 45 to 70°.

The coal outcrops on a hillside and has also been located by several shallow drill holes. The defined outcrop width is 600 meters across the hillside. There is evidence the coal could exist within a synclinal structure extending down to a depth of 500 to 1,000 meters. This structure has not been investigated as no deep drill holes have been drilled. According to Armenian geologists, there are other Jurassic coal bearing structures in Armenia that have not been investigated. Areas adjacent to this deposit also have not been geologically mapped and explored.

There is much faulting and complex structural conditions in this deposit. The visible outcrop area, where small-scale mining is taking place, displays complex faulting and is completely "sheared, squeezed, twisted and contorted, indicating a lot of tectonic deformation. The coal is sheared and broken, not really cleated" according to U.S.G.S. descriptions.

The coal was sampled by U.S.G.S. at the outcrop to develop a concept of the type and quality of the coal. Table 2-6 provides a summary of a series of 10-centimeter thick samples taken from the outcrop of the seam in the area of mining. In this sample location the total coal seam was 23 meters thick.

[5] Assessment of the Solid Fuel Resource Potential of Armenia; Brenda S. Pierce, Peter D. Warwick, and Edwin R. Landis, Open-file Report 94-149, p. 6-7, Table 1 and Table 2, Appendix 1 p. 1-4, p. 25-39.

Table 2-6
Ijevan Coal Seam Quality Sampling Data

Characteristic	ID-1	ID-2	ID-3	ID-4	ID-5	ID-6	ID-7	ID-8
Sample Interval Represented – meters	Top	5	5	5	2	2	2	2
Moisture % arb (1)	15.83	21.80	12.33	6.60	12.94	14.00	18.54	30.83
Ash arb %	70.91	47.55	15.54	26.90	23.32	48.03	40.50	21.79
Sulfur arb %	na (3)	na	na	4.77	4.12	0.90	Na	na
Calorific Value Kcal/kg mmf (2)	648	3,019	6,353	8,053	7,056	4,751	4,096	3,499
Calorific Value arb Kcal/kg	568	2,565	5,138	6,793	6,027	4,083	3,319	2,751
Volatile Matter arb %	12.27	15.05	19.13	15.65	14.58	14.05	18.97	21.37

Sample Locations	ID-1	Top of Bed	ID-5	16 Meters from top of Bed
	ID-2	5 Meters from top of Bed	ID-6	18 Meters from top of Bed
	ID-3	10 Meters from top of Bed	ID-7	20 Meters from top of Bed
	ID-4	15 Meters from top of Bed	ID-8	22 Meters from top of Bed

Note:
1: arb: as-received basis
2: mmf: moist mineral matter free basis
3: na: not available

Assuming the sampling is representative of the section being sampled, this table shows there is potential for good coal reserves because the section of the coal is rather thick. Beyond this potential, there is a fairly thick section within the seam confines that could possibly be selectively mined to produce a product with much higher calorific value. Table 2-7 below shows the average quality characteristics of the total seam as well as the higher quality section that may exist within the confines of the seam.

Table 2-7
Ijevan Seam Average and Interior Section
Coal Quality Characteristics

Quality Characteristic	Total Seam Id 2 – Id 8	Interior Section Id 3 – Id 6
Sample Interval Represented – Meters	22	14
Moisture arb (1) %	16.7	11.5
Ash arb %	32.0	28.5
Sulfur arb %	na (3)	3.3
Calorific Value mmf (2) Kcal/kb	5,260	6,350
Calorific Value arb Kcal/kg	4,380	5,510
Volatile Matter arb %	17.0	15.9

Note:
1: arb: as-received basis
2: mmf: moist mineral matter free basis
3: na: not available

If this sampling is indicative of the total deposit, then two major criteria would have been found in the Ijevan deposit that to date have not been found in the remainder of Armenia. These two important criteria are thickness combined with a potential for higher quality coal. It is of interest to note that an as-received quality as high as 5,500 kcal/kg (9,900 btu/lb.) may be mineable from within the interior of the seam over a 14-meter thickness. Reference to the limited sampling notes indicates sections 15 through 18 visibly appear to be the best sections of coal.

It may be, therefore, that a five-meter section of significantly higher quality coal exists within the confines of the coal bed. If this is the case, then one could project a 600-meter length and an 800-meter depth, and an in-bed volume of coal equal to about four million tonnes, assuming a density of 1.6 g/cm^3. Assuming the full bed thickness of 22 meters, then 17 million tonnes of resource may be in place. A 50% underground mining recovery rate would reduce the recoverable reserves in this deposit down to two million and 8.5 million tonnes, respectively, if it is economic to recover the reserves. This reserve estimate appears to correlate to the C2 reserve estimate of 9.8 million tonnes calculated by the Armenian professionals and shown in Table 2-2.

If an average calorific value of 4,400 kcal/kg could be produced by mining the 22-meter thick seam, then roughly 10 million tonnes of coal would be necessary for the power station life of 35 years. It appears there may be adequate volume in this reserve if lateral boundaries of the resource can be expanded. Lateral expansion would also be of value in reducing the depths of mining projected here to obtain the reserves needed to support the power station.

The reserve at Ijevan could only be mined by underground mining methods in order to develop reserves of any magnitude. It is expected that a mining method such as the breast-and-pillar method used in the anthracite coal sector in the Appalachian coal region of the eastern United States could be employed at this site. This is a labor-intensive method employing limited mechanized mining equipment because of the difficulty of using such equipment in such steeply dipping conditions. A method somewhat similar to this is employed at the Tkibuli mine in Georgia. Given that labor rates are currently low in Armenia, it may be economic to employ such a mining method. Because this method is no longer used in the U.S. it is difficult to project at this point in time whether such a venture in Armenia could be economic. It is known, however, that the professionals at the Tkibuli mine are of the opinion that their project, which produces a similar quality coal using a similar method, is indeed economic.

The Ijevan deposit is described as geologically complex and faulted. There is a chance the deposit has been so massively impacted by geologic events that the deposit will be very difficult to mine. Complex faulting may have destroyed the integrity of the overlying and underlying non-coal beds such that it will be impossible to economically support underground mine openings long enough to acquire the coal. Major fault structures could also reduce available coal reserves and disrupt mining efforts. There could also be water problems associated with the faults that could make mining more difficult and expensive. It is also not known how well the immediate roof structure, which has been described as a tuffaceous clay, will be able to act as a roof for mining operations.

All in all, this deposit may have adequate resources to support a 50 MW coal-fired power station but additional resources need to be found beyond the current limits of the known resource. If adequate resources do exist, two major conditions may prevent the economic mining of coal from the deposit. First, a labor-intensive underground mining method will be necessary and Armenian experience with underground coal mining techniques is non-existent. Second, the geologic conditions with the deposit may be so complex or of a nature that mining of the deposit would be too expensive. On a positive note, the deposit location is in an area that provides ready access to a labor force, available infrastructure, and rail access. At this point in time, inadequate information is available to properly assess the likely feasibility of the mining concept.

Further exploration is recommended to gather additional information about the Ijevan deposit. This deposit is likely marginally economic, as are most deposits in Armenia, but it falls within the confines of the task that has been established for this program. It is suggested that an independent mining engineer be involved to analyze the plan for additional exploration as well as to review the results of the program.

The decision of whether to go forward with this project is difficult to make. There are no guidelines established upon which a reasonable decision can be made. It is necessary that more concrete parameters be established to guide this decision-making process before additional work effort is expended. The effort to develop economic coal reserves in Armenia has shown that the reserves in Armenia are marginally economic and that the likelihood of finding low-cost economic reserves might be rather remote.

The information provided in this report and any subsequent economic analysis relative to a coal-fired power station should be employed to determine the likely cost of developing a domestic fuel resource. This information should be used to assess how more expensive or non-economic ventures would be paid for on an annual basis as well as financed for initial construction. This exercise should be used to make rational decisions concerning the country's ability to support an expensive or non-economic energy security policy. Having an established set of guidelines would be invaluable to evaluate the Ijevan coal deposit as well as to determine if it is sensible to evaluate the Dilijan oil shale deposit any further.